

YABBIES AT DALHOUSIE SPRINGS, NORTHERN SOUTH AUSTRALIA: MORPHOLOGICAL EVIDENCE FOR LONG TERM ISOLATION

This paper stems from a comprehensive morphological analysis of the taxonomy of the *destructor* group of the genus *Cherax*.^{1,2} Since the specimens from Dalhousie Springs proved to be morphologically distinct from all other specimens examined, they are given special consideration here.

Dalhousie Springs are a series of over 60 active mound springs distributed throughout an area of about 60 km², 160 km NE of Oodnadatta in the far north of South Australia.³ While located within the Lake Eyre Drainage division; they are isolated from the major waterways and lakes of central Australia.

Morphological analyses included both bivariate (analysis of covariance) and multivariate (principal components analysis) techniques.^{1,2} On the basis of fifty metric and multistate characters, the specimens from Dalhousie Springs are closest to *C. destructor*, which is the only other species of *Cherax* to be found in central Australia.⁴ Of these characters, the Dalhousie Springs specimens could be distinguished statistically from *C. destructor* by their relatively broad areola (the distance between the branchiocardiac grooves), short thorax, and short rostrum; and to a lesser extent by relatively large chelae and broad rostrum.¹ These characters are illustrated in Fig. 1.

The Dalhousie Springs specimens are separated most conspicuously from *C. destructor* by their relatively broad areola. The relationship between areola width and ocular-carapace length for the Dalhousie Springs specimens (a), *C. albidus* (b) and *C. destructor* (c) is shown in Fig. 2. The data for Dalhousie Springs specimens represent collections from several mound Springs. These data were log-transformed to linearize the allometric relationship of areola width with ocular-carapace length. Analysis of covariance indicated that the elevations of these regression lines are significantly different ($F_{2,1497} = 611.1$, $p < 0.001$). *A posteriori* comparison of the elevations using Tukey's Test⁵ indicated that the differences between each pair of lines are statistically significant ($p < 0.05$), with the Dalhousie Springs specimens having the broadest areolae and *C. destructor* having the narrowest.

Dalhousie Springs are thought to have formed during the late Pliocene-early Pleistocene and the surrounding area has been substantially dry since the late Tertiary.^{6,7} However, in modern times, flood waters from the creeks near the springs would have provided a connection between the springs and the Finke river system via spring run-off during particularly wet years.⁷ It has been suggested that these conditions may have occurred numerous times in the past 1000 years and possibly more frequently during the Pleistocene when the springs may have been at a relatively lower elevation.⁷ In the light of these suggestions, it is interesting that these populations have maintained their morphological integrity, probably in the face of repeated invasion by *C. destructor*. One explanation for this may be that the yabbies of Dalhousie Springs may have developed physiological tolerance of the high, relatively constant temperature to which they are exposed. Invading *C. destructor* may not be able to survive

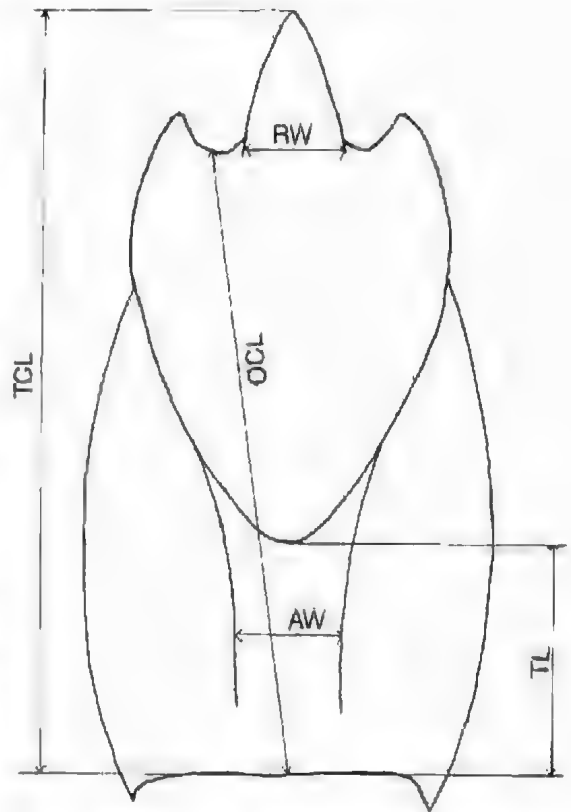


Fig. 1. Cephalothoracic measurements distinguishing the Dalhousie Springs yabbies from other specimens of *C. destructor*. TCL, total-carapace length; OCL, ocular-carapace length; TL, thorax length; RW, rostrum width; AW, areola width. Rostrum length was calculated as the difference between TCL and OCL.

and reproduce under these conditions. Ecological isolation of populations between which there are no geographical barriers has been described for some species of *Gammarus* which inhabit regions with differing salinities.⁸ Individuals from different populations of some "species" were so specialized that they could not survive and reproduce at any common salinity.

On the basis of zoogeographic evidence not connected with Dalhousie Springs, I have previously postulated that *C. destructor* arose as a result of increased selection for drought tolerance during the late Tertiary-Pleistocene phase of increasing aridity and that it arose from a previously widespread "*C. albidus*-like" ancestor.^{1,2} This latter species is now restricted to southwestern Victoria and the extreme southeast of South Australia. The similarity of the Dalhousie Springs specimens to *C. albidus*, with respect to relative areola width is, therefore, particularly significant. Mound springs also have been suggested as providing refuges for aquatic fauna

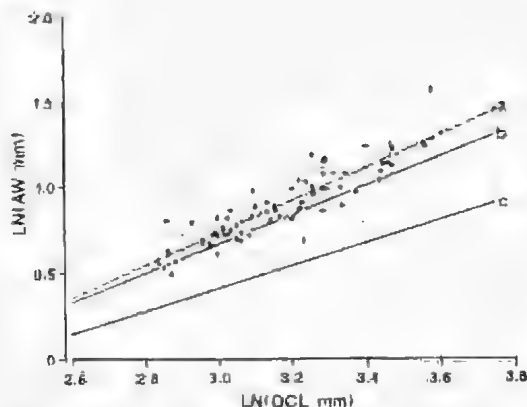


Fig. 2. Lines of best fit for the log-log regressions of areola width on ocular-carapace length. a, Dalhousie Springs ($n=75$); b, *C. albidus* ($n=526$); c, *C. destructor* ($n=900$). All regressions are statistically significant ($p < 0.001$). The circles indicate the positions of individuals from Dalhousie Springs.

during periods of increased aridity.⁹ An association between areola width and the environment has been noted for cambarid species, wide areolae being largely restricted to highly oxygenated lotic habitats and narrow areolae being more common on crayfish inhabiting waters of lower oxygen concentrations.^{10,11} This association was related to the fact that a lengthening and narrowing of the areola will result in a concomitant enlargement in the gill chamber.¹⁰ We might therefore predict that a drought-adapted species (i.e. *C. destructor*) would have a relatively narrow areola. As *C. destructor* populations inhabiting the cooler, wetter areas of central Victoria and southeastern New South Wales do not show any broadening of the areola,^{1,2} this relationship (if it applies to parastacids) is not a proximal one.

Although the Spring water temperatures are high, dissolved oxygen levels are generally high to saturated in most springs, except in the immediate vicinity of the vent.⁹ The permanent water of the mound springs would, therefore, buffer the crayfish from the effects of aridity and subsequent selection for drought tolerance. For further interpretation of the pattern of morphological variation, it would be interesting to know whether there has been gene flow between the Dalhousie Springs crayfish and typical *C. destructor*. Future investigation using other methods (e.g. immunological techniques) may help to clarify the relationships between the Dalhousie Springs populations, *C. destructor* and *C. albidus*.

Although these specimens are morphologically very distinct from the other *C. destructor* specimens, their taxonomic status is far from clear. The possibility that their distinctive morphology is environmentally induced must be considered. The Dalhousie mound springs represent an extreme environment. Spring water temperatures at the source vary from 29°C to 44°C, the hotter springs being in the north.¹² While summer water temperatures may reach these levels in other parts of central Australia, the spring water temperatures are constant throughout the year, at least at the source. These springs rarely flow more than 15 km from their source due to the high evaporation

rate (2500 mm/annum).¹² If the unusual morphology of the Dalhousie Springs specimens is environmentally induced, some indication of morphological similarity with other central Australian populations might be expected. However, with respect to the characters which distinguish the Spring specimens, yabbies from other northern South Australian, southern Northern Territory and southwest Queensland localities are closer to southeast Australian specimens.^{1,2}

A further indication of the extreme environment at Dalhousie Springs is the presence of berried females of very small carapace lengths. I have examined berried females of total carapace length (TCL) 23.4 mm (OCL 19.8 mm) and 24.3 mm (OCL 20.6 mm) from this locality. Previous field studies have recorded minimum total carapace lengths (TCLs) for berried females of 31–45 mm,¹¹ although berried females of total carapace length as small as 26 mm have been recorded from Lake Eucumbene in southeastern N.S.W.¹⁴ The Dalhousie Springs specimens therefore represent the smallest berried females of "*C. destructor*" yet recorded. The size at which crustaceans reach sexual maturity in the field has been suggested to be a gauge of the influence of the environment on the performance of the population.¹⁵

A further complication is the possibility of recent introductions. Yabbies were first recorded from the Springs in May 1984 when they were collected using wire-mesh box traps for fish.¹⁶ However, no *Cherax* were collected on previous visits in July/August, 1968, November, 1969, and May, 1974 using the same traps in the same area. When collecting yabbies, however, it is not unusual to have markedly different trapping success at different times. It has also been noted that locals in the mid-north of South Australia, at least as far north as Oodnadatta, have introduced yabbies into their dams.¹⁷ Given that the morphology of the Dalhousie Springs crayfish is so distinct from all other *C. destructor* populations examined,^{1,2} it is most unlikely that they are the result of recent introductions by man.

While the frequency and extent of past aquatic connections between the Dalhousie Springs and surrounding drainage systems are not known, conditions favouring speciation of other taxa have existed since there are two endemic fish species, the Dalhousie catfish (*Neosilurus* sp.) and the Dalhousie hardyhead (*Craterocephalus dalhousiensis*) which cannot survive at water temperatures much less than 20°C.^{18,19,20} Dalhousie Springs also contains endemic snails (family Hydrobiidae) and amphipods.⁹

The cause of the unique morphology of the Dalhousie Springs specimens (i.e. genetic or environmental) may be solved by the rearing of young under controlled conditions. The replication of this procedure with "good" *C. destructor* would serve as a control. Without this further evidence, however, firm taxonomic conclusions are not justified.

I am indebted to Dr Sam Lake for his constructive criticism and suggestions. My thanks also go to Dr Ian Bayly and Michael Barry for their comments on this manuscript.

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**MIDDLE EOCENE AGE OF THE MEGAFOSSIL FLORA AT GOLDEN
GROVE, SOUTH AUSTRALIA: PRELIMINARY REPORT, AND
COMPARISON WITH THE MASLIN BAY FLORA**

Summary